



Probability of US regional tornado outbreaks and its link to springtime ENSO phase evolution

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Outline

- **Motivation and background**
- **Four dominant phases of springtime ENSO evolution**
- **Probability of US regional tornado outbreaks**
- **Springtime ENSO phases and U.S. regional tornado outbreaks**



US National Hazard Statistics for 2013

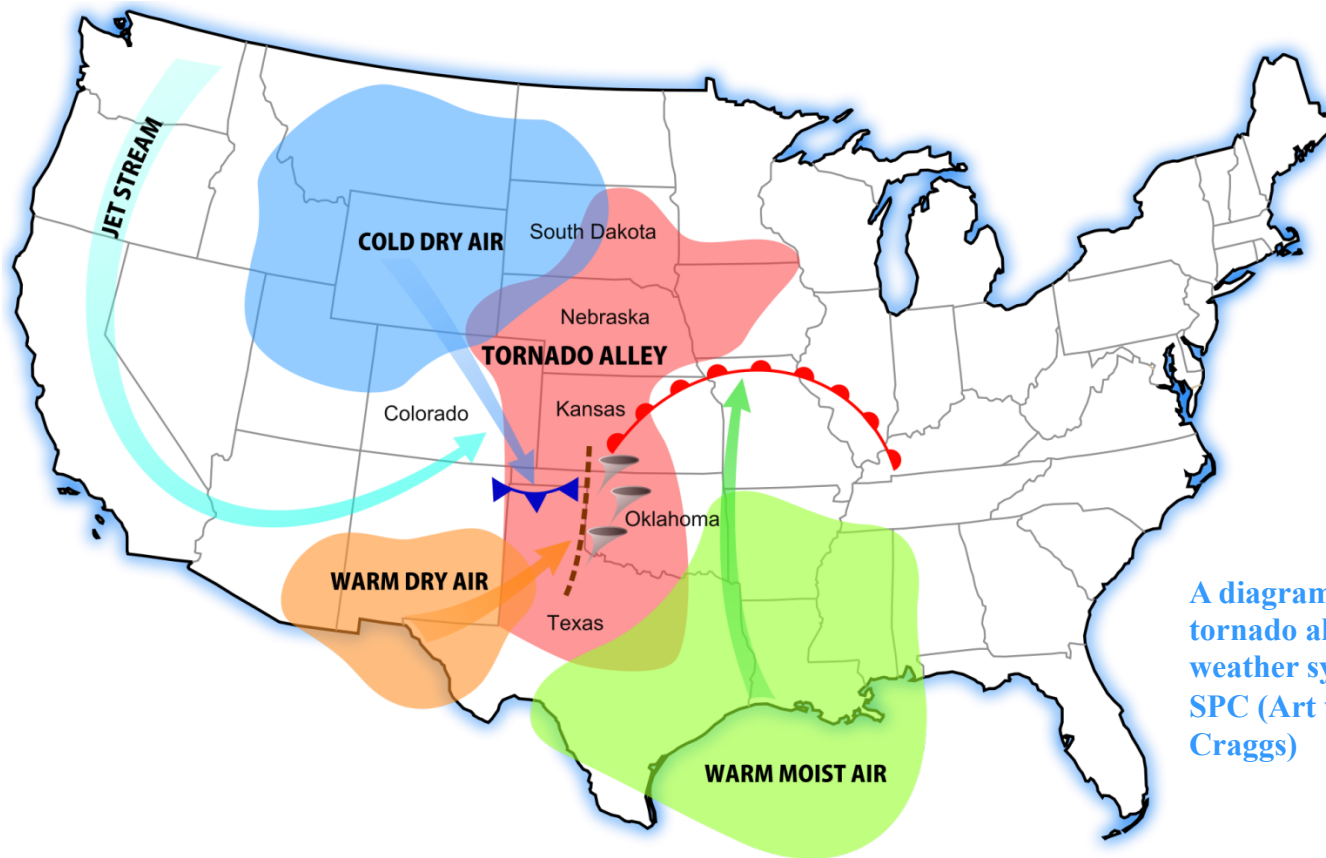


Tornado-related fatalities, injuries & damage costs

Year	Fatalities	Injuries	Property & crop damage (M)
2004	35	396	549.2
2005	38	537	503.9
2006	64	990	759.0
2007	81	659	1,407.5
2008	126	1,714	1,865.6
2009	21	351	584.9
2010	45	699	1,134.6
2011	553	5,483	9,493.0
2012	70	822	1,649.7
2013	55	756	3,648.7
Total	1,091	12,407	21,596.1

- During 2004-2013, tornadoes claimed 1,091 lives in the U.S. and caused 21.6 billion dollars in property and crop damages
- The tornado-related death toll only trails behind heat-related fatalities
- Expanding the current severe weather outlooks beyond 7 days will help emergency managers, government officials, businesses and the public to better prepare their resources to make smart decisions to save lives

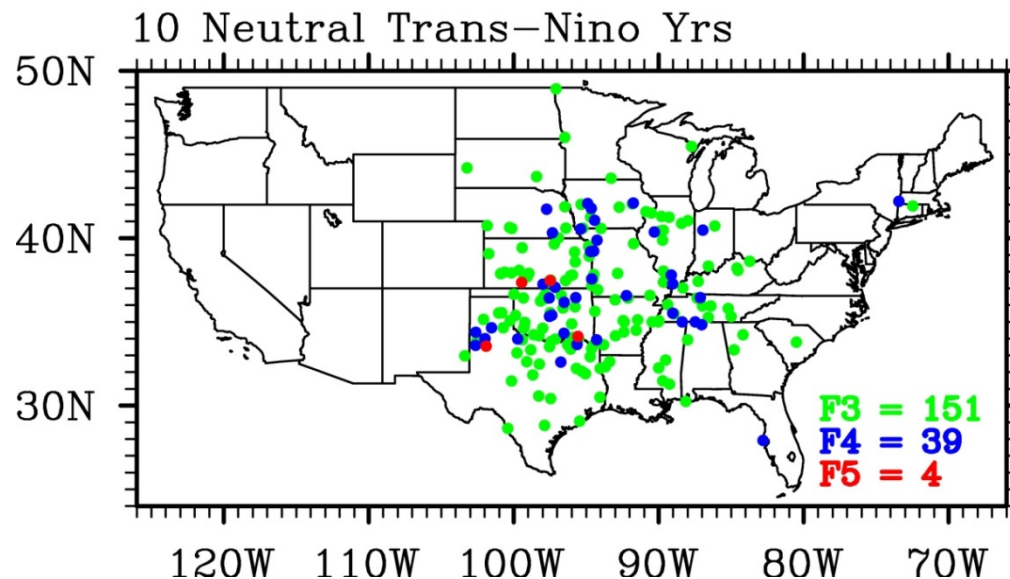
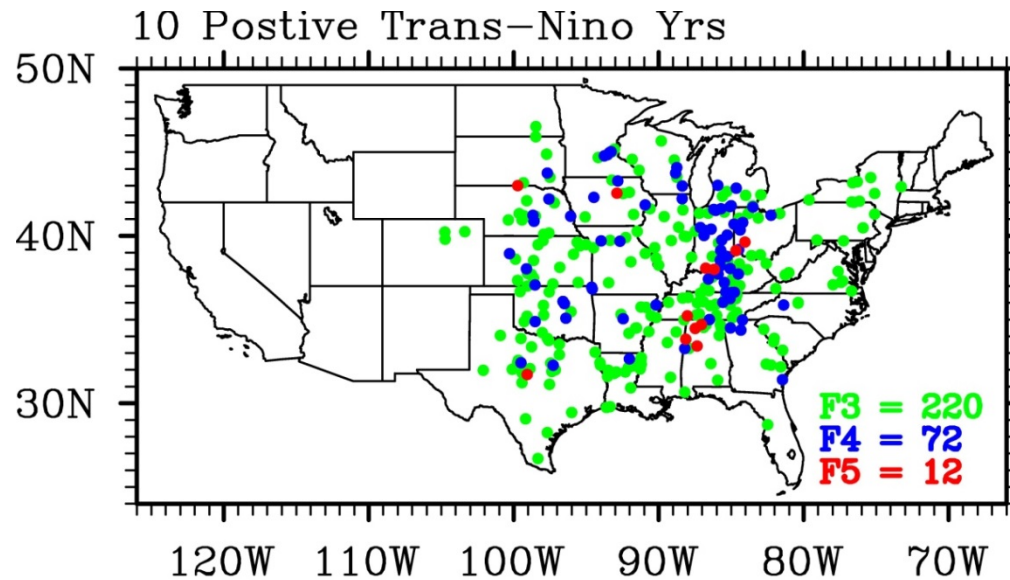
US atmospheric conditions in spring



A diagram of the location of tornado alley and the related weather systems from NOAA SPC (Art work by Dan Craggs)

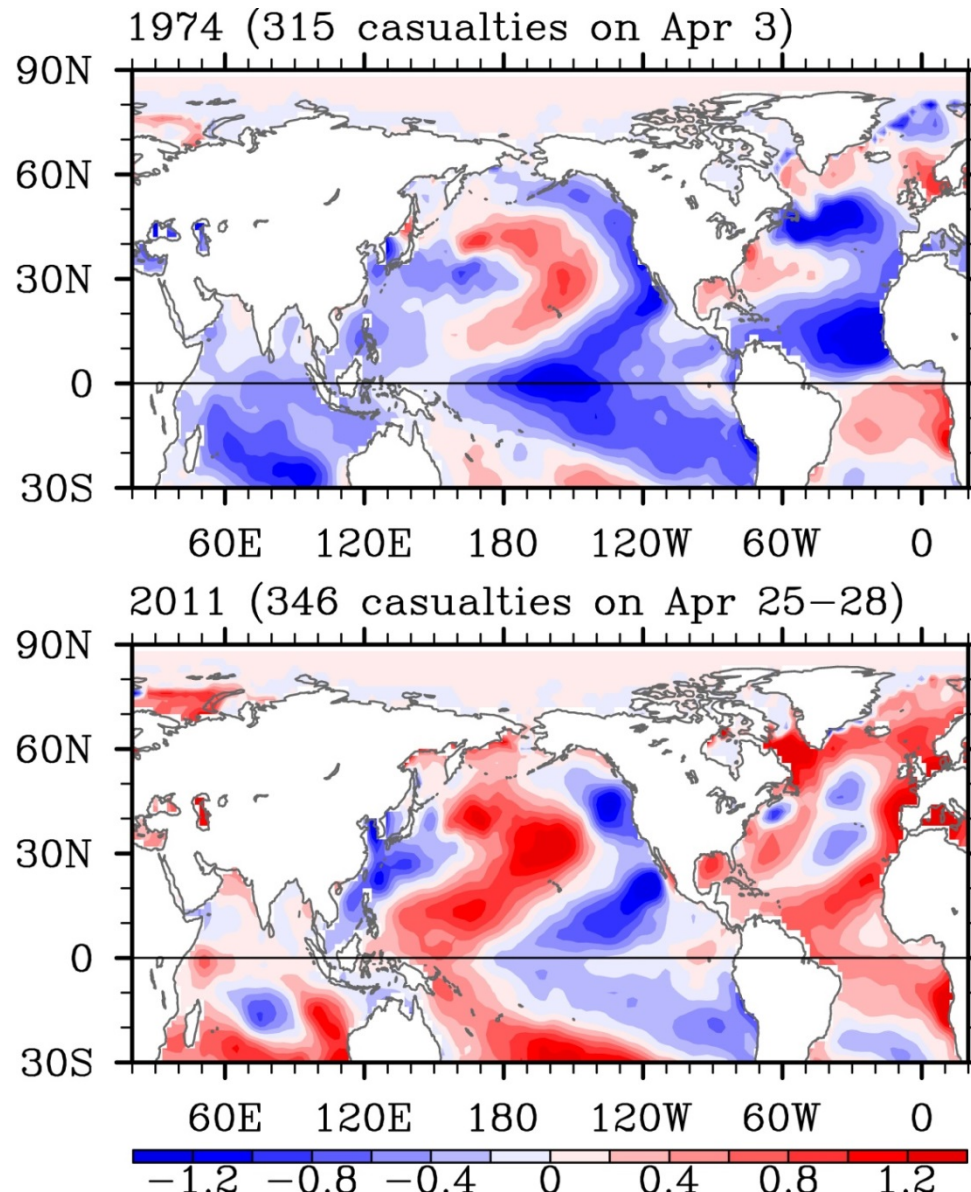
- Over the central US in spring, cold & dry upper-level air collides with warm & moist low-level air from the Gulf of Mexico (large-scale differential advection).
- CAPE & low-level shear provide a favorable environment to form a supercell, linked to tornado genesis (e.g., Lemon and Doswell, 1979).

Background: Lee et al. (2013, JCLI)



- The number of intense (F3 - F5) tornadoes nearly doubled during (+) Trans-Niño years.
- During 1951 – 2010, 7 out of 10 extreme US tornado outbreaks (including the top 3) occurred in (+) Trans-Niño years.
- Trans-Niño is one of many phases of ENSO first identified by Trenberth and Stepaniak (2001).
- It is also known as Modoki ENSO, PMM, CP ENSO, WP ENSO and etc.

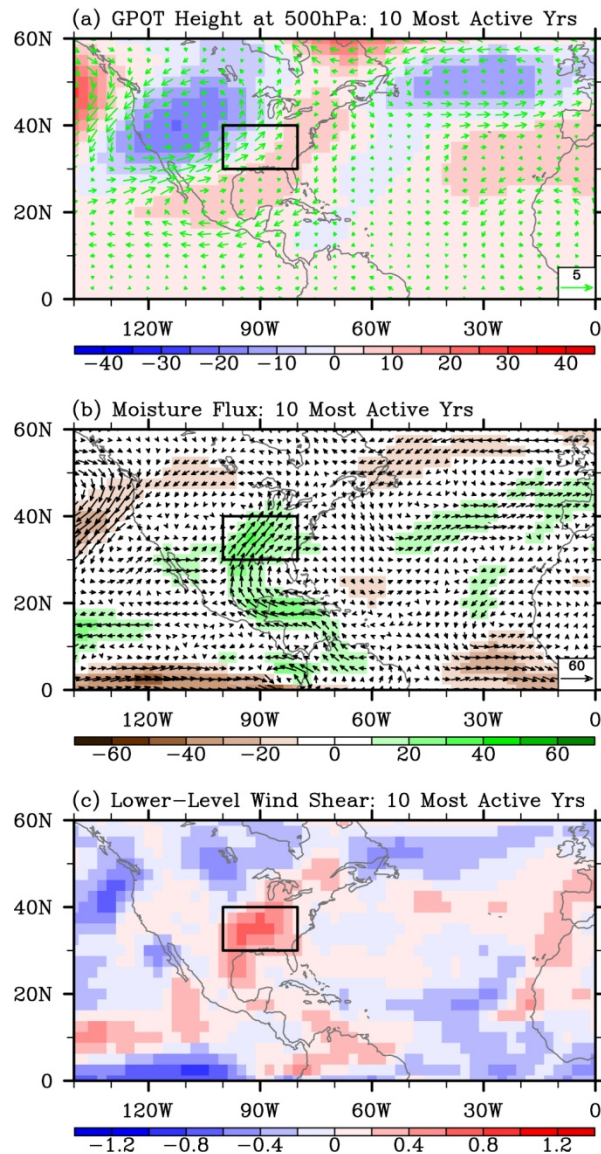
Background: Lee et al. (2013, JCLI)



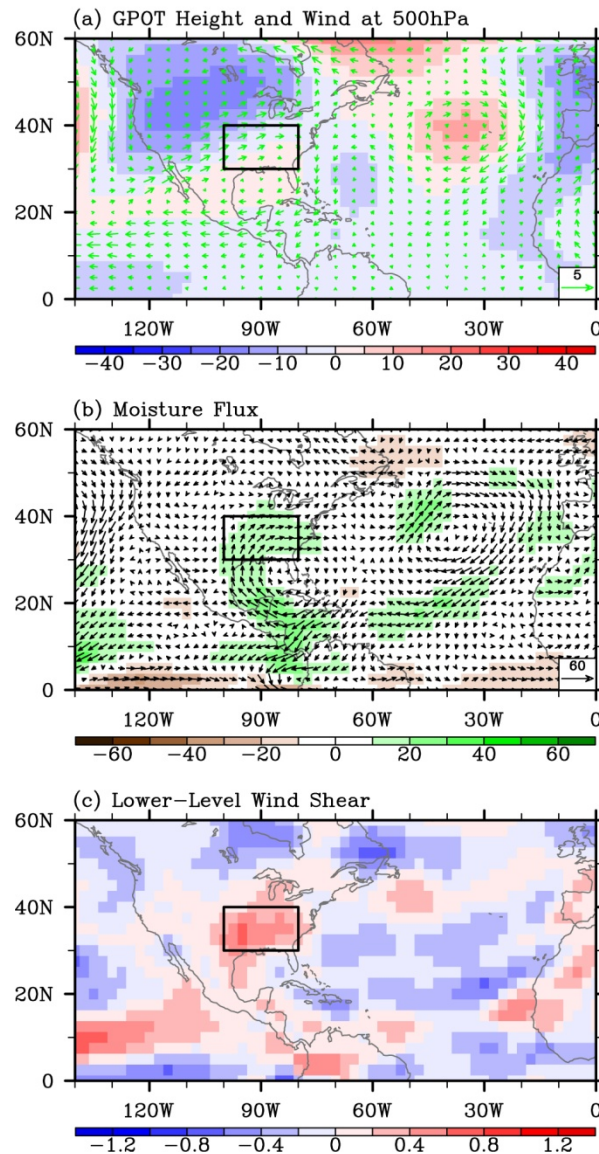
- (+) Trans-Niño: zonal gradient of SST anomalies along the equatorial Pacific between CP & EP > 0 .
- (+) Trans-Niño typically occurs in the boreal spring following the peak of La Niña.
- Five historic tornado outbreak years (1917, 1925, 1936, 1974 and 2011) were all (+) Trans-Niño years.

Background: Lee et al. (2013, JCLI)

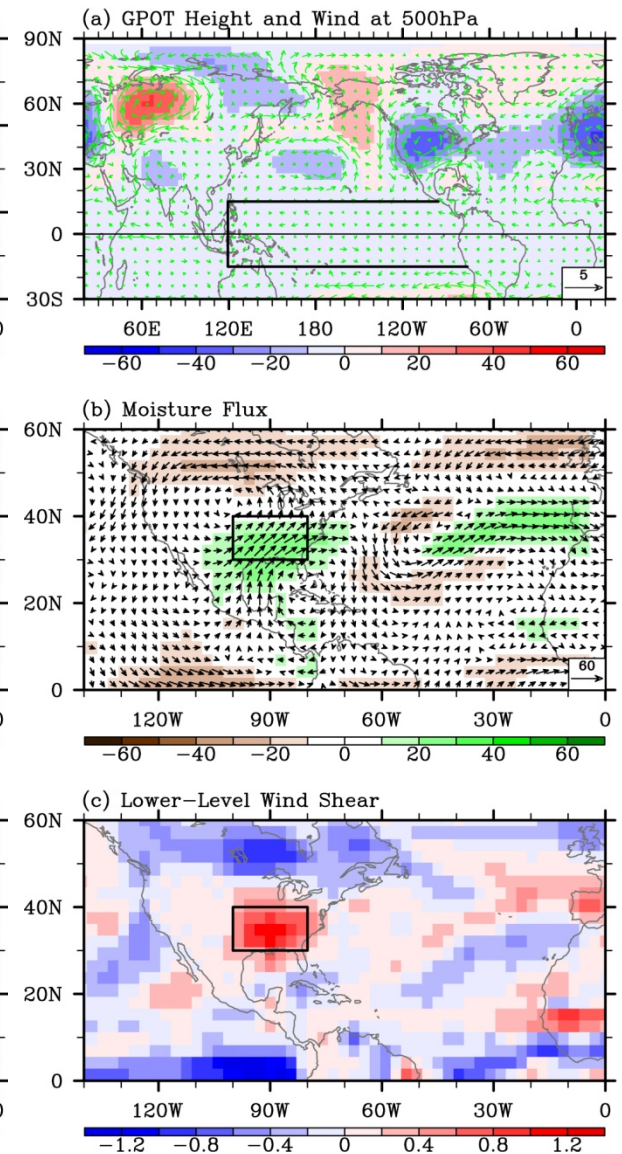
10 Most Active Yrs



10 (+) Trans-Niño Yrs

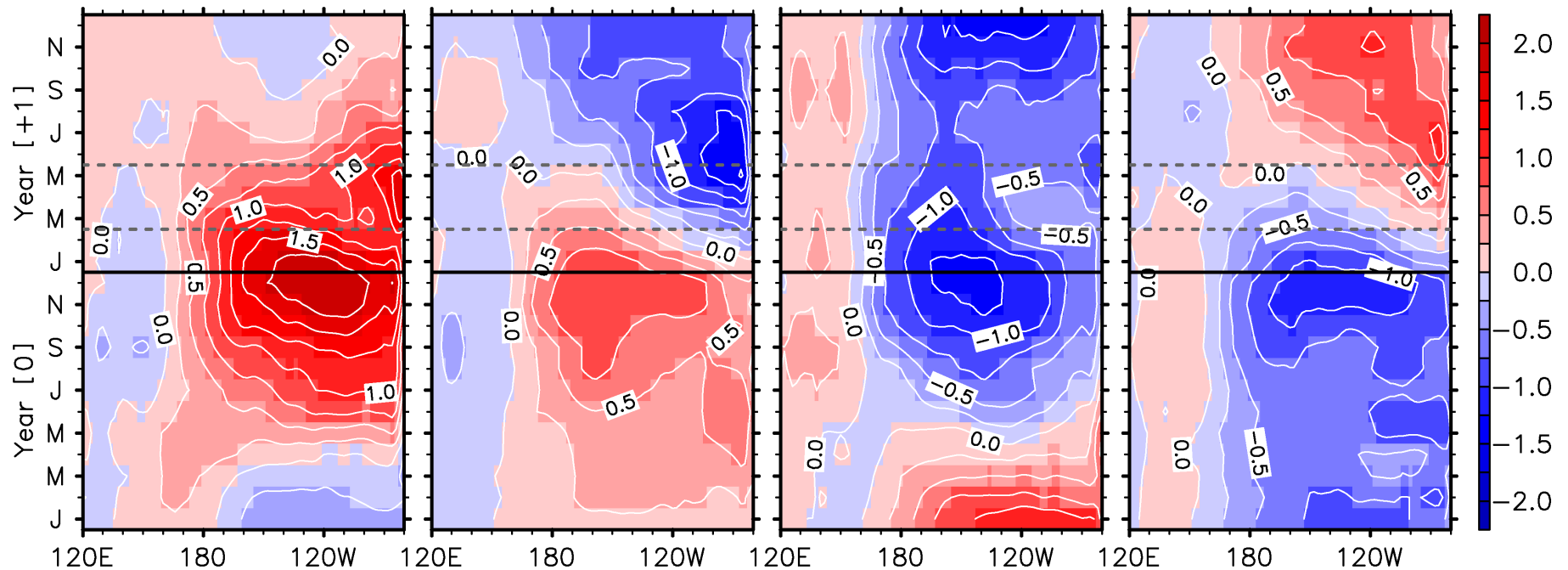


CAM3-SOM



Springtime ENSO phase evolution

Four dominant phases of ENSO evolution



- A recent study used an objective method to identify 4 dominant phases of springtime ENSO evolution (Lee et al., 2014, GRL).
- El Niño: Persistent (strong) & early-terminating (weak)
- La Niña: Resurgent & transitioning (early-terminating)



Probability of regional tornado outbreaks

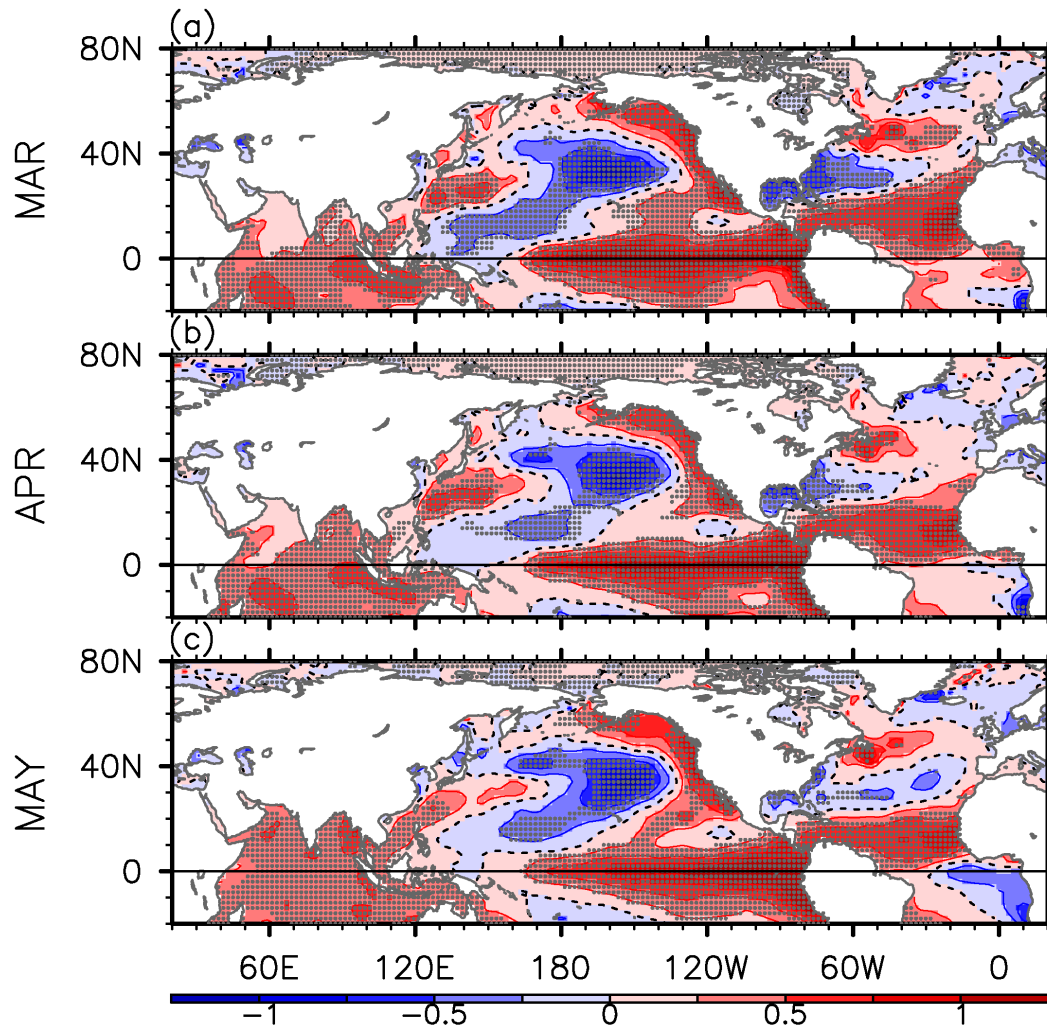


- **To move forward with the goal to develop a seasonal outlook for U.S. tornado outbreaks, we propose a new index, which can be used as a seasonal tornado outlook metric.**
- **This new index measures the probability that a localized tornado outbreak may occur in a predefined region.**
 1. **Count the number of F1-F5 tornadoes for $1^\circ \times 1^\circ$ grid boxes over the US for each month and year.**
 2. **For each point, month and year, find the regional maximum number of F1-F5 tornadoes within a circle of 3° radius.**
 3. **Then, identify whether the regional maximum number exceeds the regional mean + STD (Yes = 1 and No = 0).**
 4. **For a subset of data, count the number of outbreak years and perform Chi-square significance test (90% in this study).**

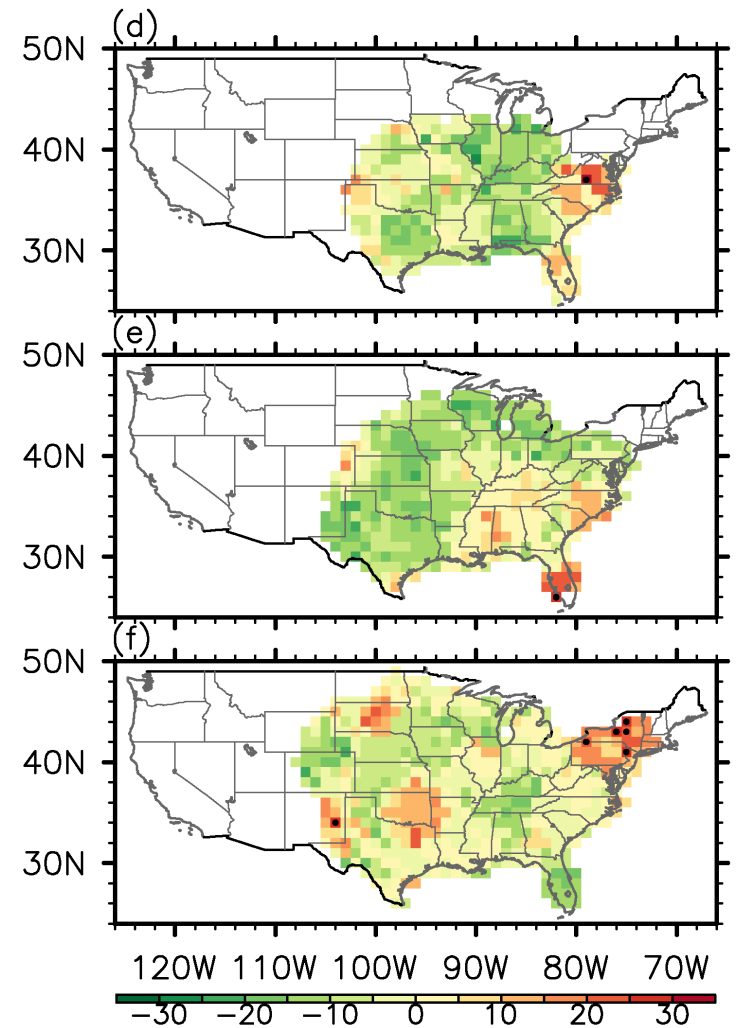
Springtime ENSO phase evolution & probability of US regional tornado outbreaks

El Nino [+1] Year: SSTA and Probability of Tornado Outbreak

Persistent El Nino: SST Anomalies



Persistent El Nino: Outbreak Chance

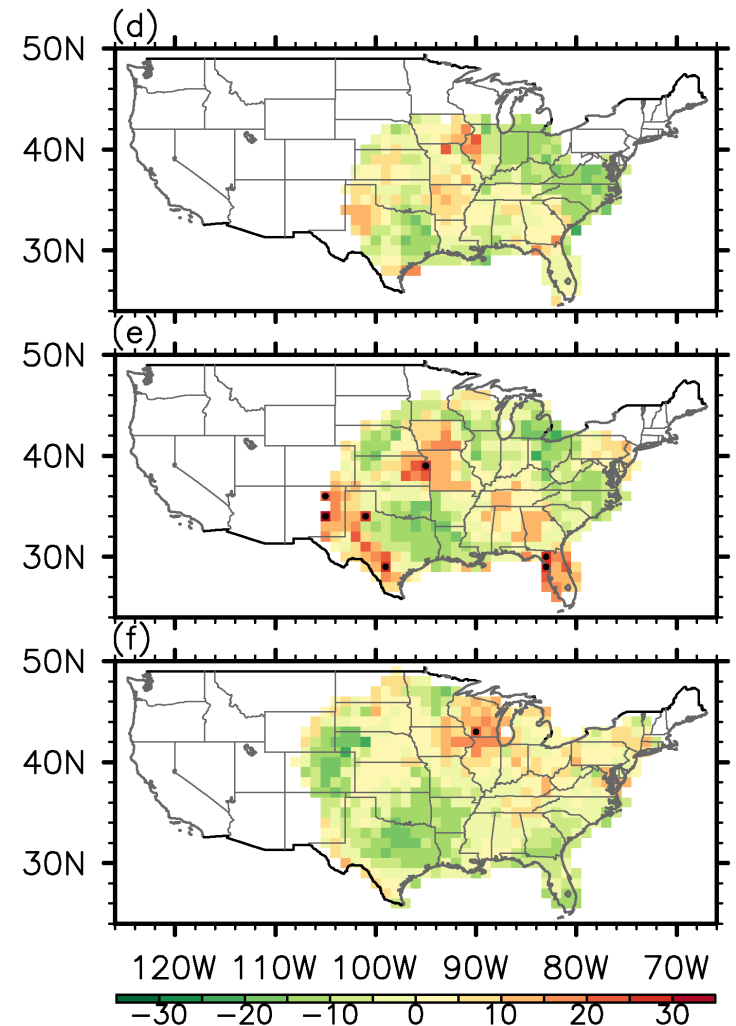
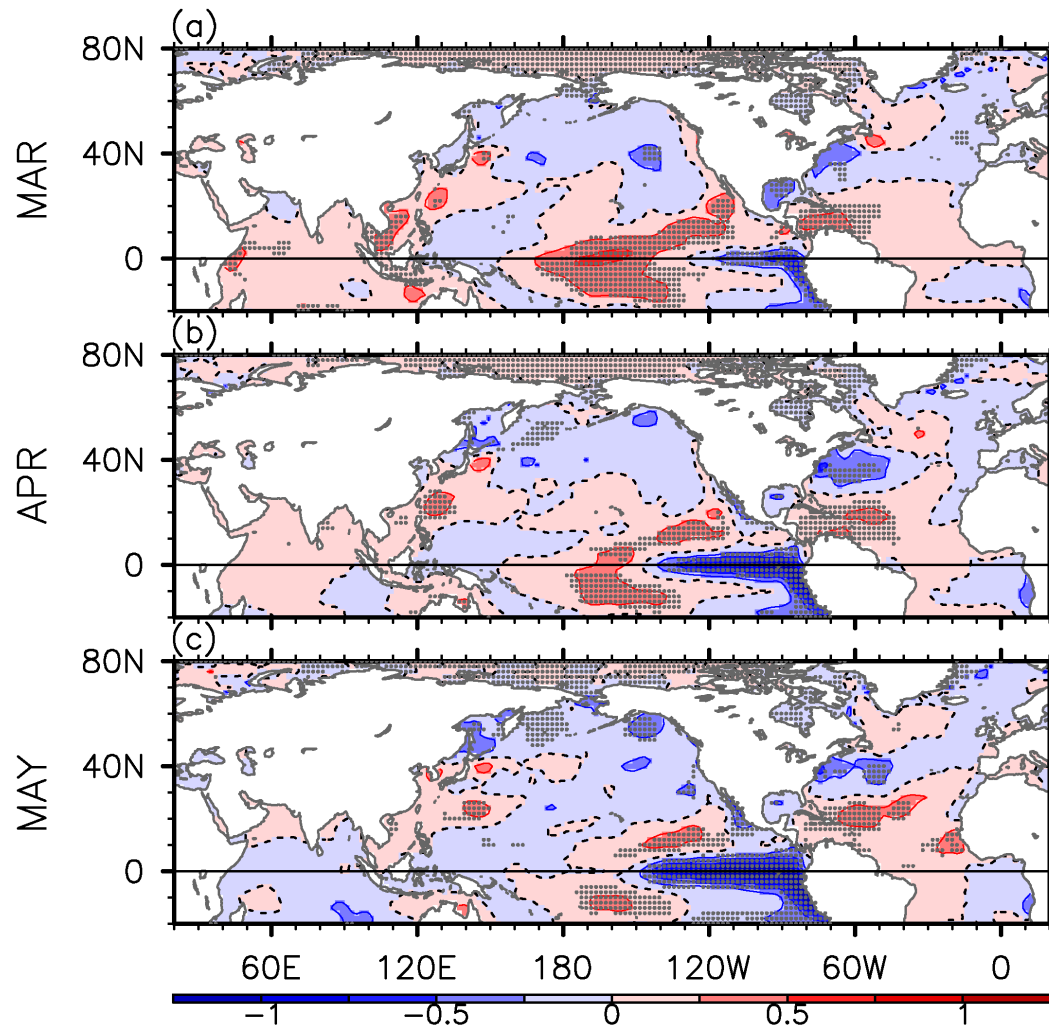


Springtime ENSO phase evolution & probability of US regional tornado outbreaks

El Nino [+1] Year: SSTA and Probability of Tornado Outbreak

Weak El Nino: SST Anomalies

Weak El Nino: Outbreak Chance

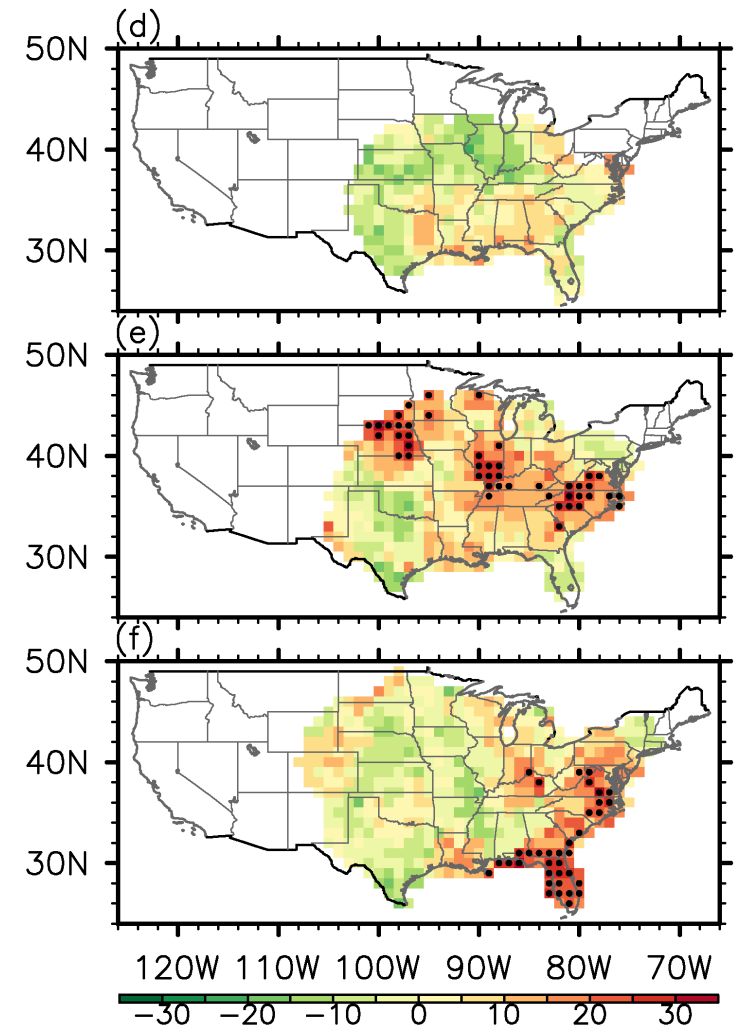
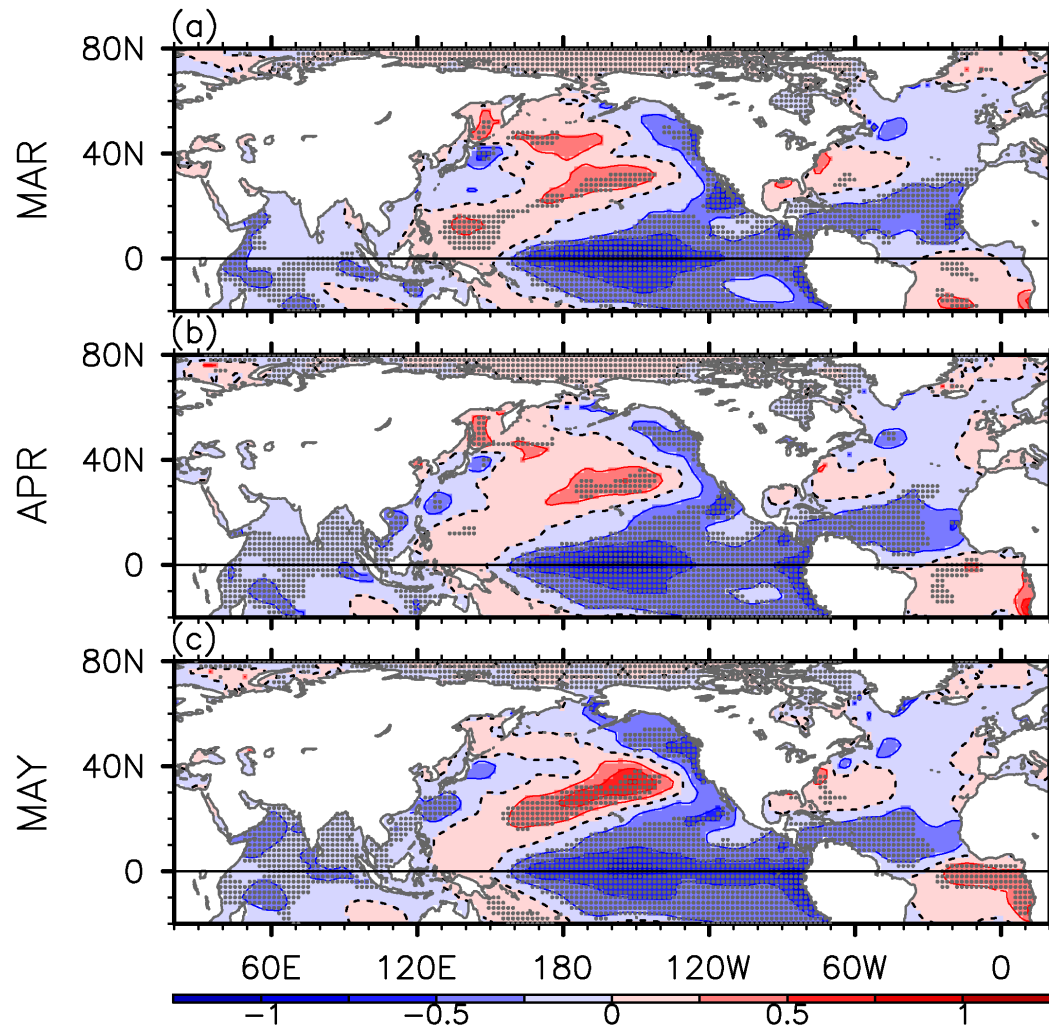


Springtime ENSO phase evolution & probability of US regional tornado outbreaks

La Nina [+1] Year: SSTA and Probability of Tornado Outbreak

Persistent La Nina: SST Anomalies

Persistent La Nina: Outbreak Chance

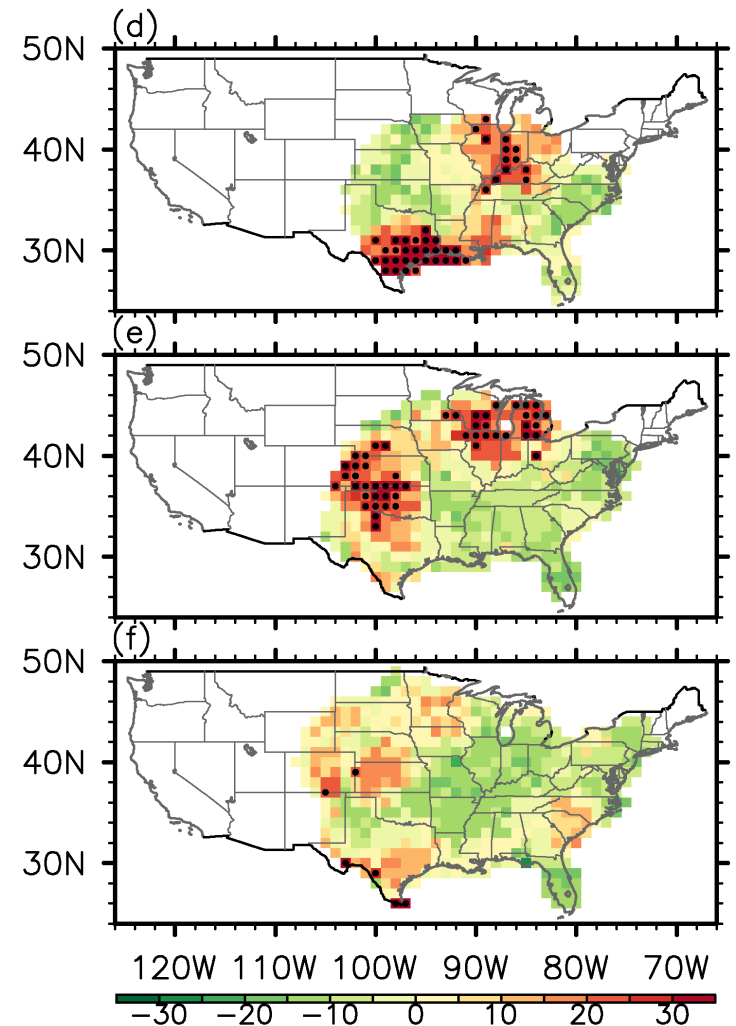
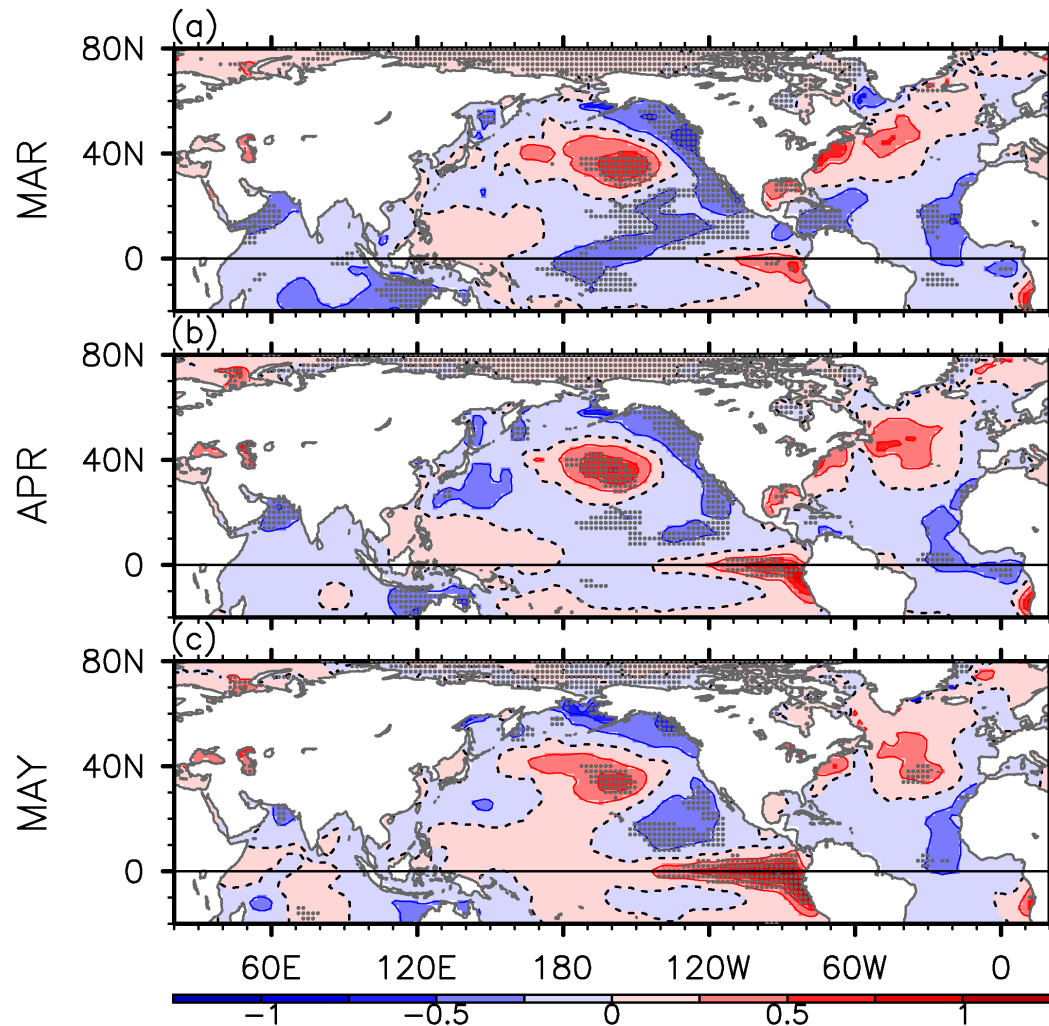


Springtime ENSO phase evolution & probability of US regional tornado outbreaks

La Nina [+1] Year: SSTA and Probability of Tornado Outbreak

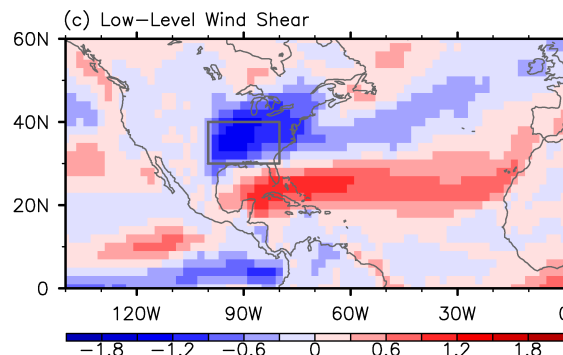
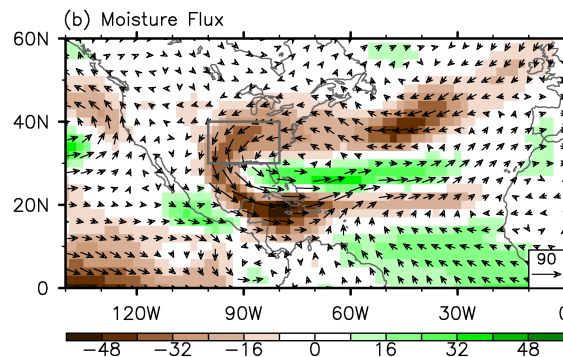
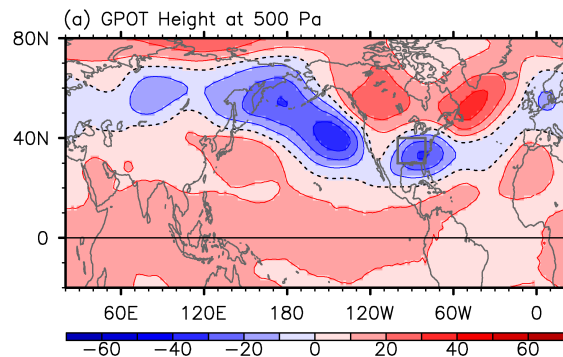
Transition La Nina: SST Anomalies

Transition La Nina: Outbreak Chance

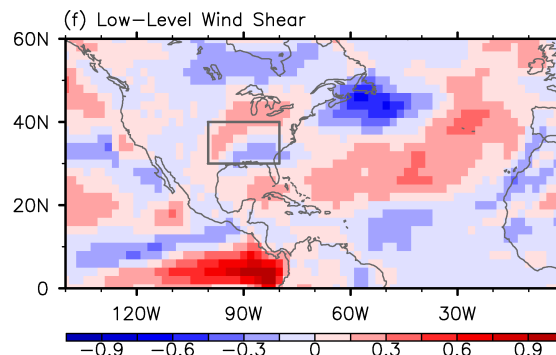
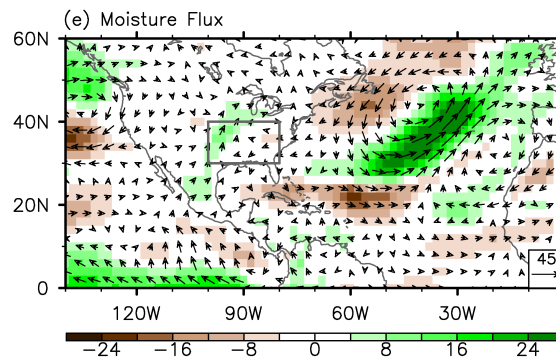
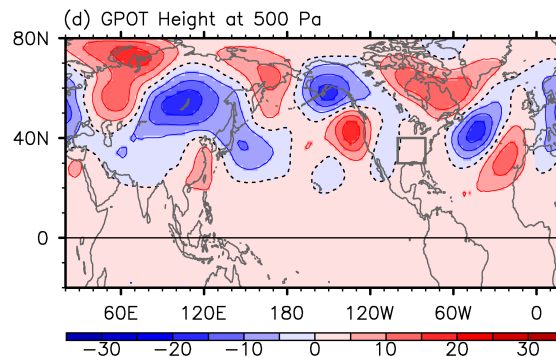


Springtime ENSO phase evolution and associated atmospheric anomalies

Persistent El Niño (MAM)



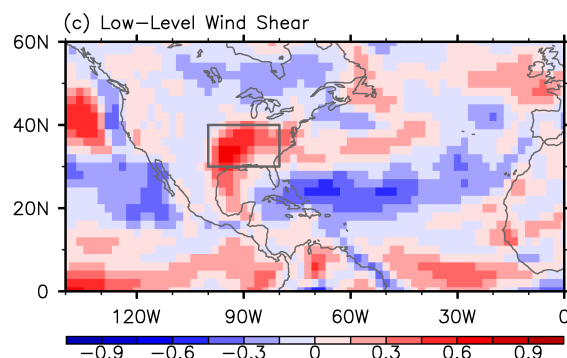
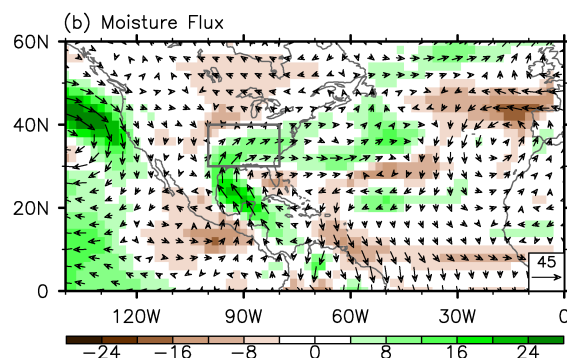
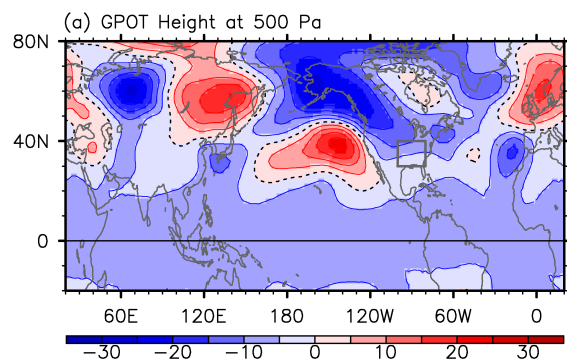
Early-terminating El Niño (MAM)



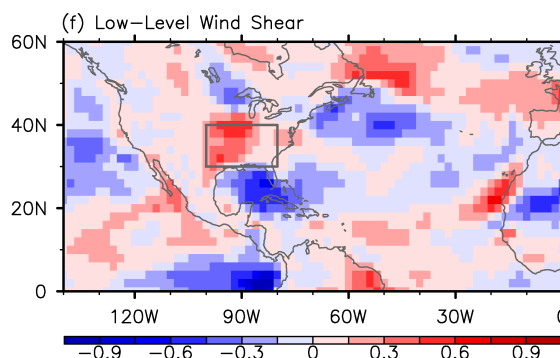
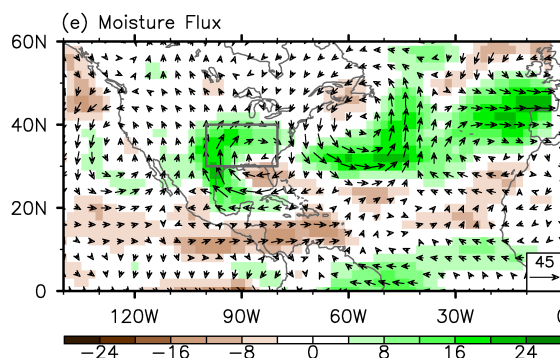
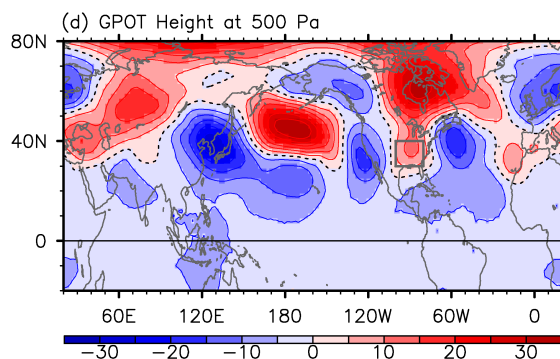
- Atmospheric conditions under persistent El Niño phase unfavorable for tornado outbreaks in the US.
- During persistent El Niño phase, the GoM-to-US moisture transport decreases.
- The low-level wind shear also decreases over the US.

Springtime ENSO phase evolution and associated atmospheric anomalies

Resurgent La Nina (APR-MAY)



Transitioning La Nina (MAR-APR)



- Atmospheric conditions under persistent and transition La Nina phases favorable for tornado outbreaks in the US.
- In both phases, the GoM-to-US moisture transport increases.
- The low-level wind shear also increases over the US.



Summary



- ***“Probability of US regional tornado outbreaks”*** is proposed as a new tornado index, and applied to measure tornado activity under 4 dominant phases of springtime ENSO evolution.
- **Persistent El Niño phase is linked to large-scale atmospheric anomalies unfavorable for tornado outbreaks in the US. However, the probability of US regional tornado outbreaks is not significantly reduced.**
- **Resurgent La Niña is linked to significantly increased probability of tornado outbreaks in the central and southeast US.**
- **Transitioning La Niña is linked to significantly increased probability of tornado outbreaks in the south, central and upper midwest US.**



Summary



Regions of increased probability of tornado outbreaks

Springtime ENSO phases	March	April	May
Persistent El Niño	-	-	-
Early-terminating El Niño	-	-	-
Resurgent La Niña	-	NE, Central (IL) and Southeast (VA & NC)	Southeast (VA, NC & FL)
Transitioning La Niña	Central (IN & KY) and South (TX)	Upper Midwest (WI & MI) and South (TX, OK & KS)	-



References



- **Lee, S.-K., P. N. DiNezio, E.-S. Chung, S.-W. Yeh, A. T. Wittenberg and C. Wang, 2014: Spring persistence, transition and resurgence of El Nino. Geophys. Res. Lett., 41, 8578-8585, doi: 10.1002/2014GL062484.**
- **Lee, S.-K., B. E. Mapes, C. Wang, D. B. Enfield and S. J. Weaver, 2014: Springtime ENSO phase evolution and its relation to rainfall in the continental U.S. Geophys. Res. Lett., 41, 1673-1680, doi: 10.1002/2013GL059137.**
- **Lee, S.-K., R. Atlas, D. B. Enfield, C. Wang and H. Liu, 2013: Is there an optimal ENSO pattern that enhances large-scale atmospheric processes conducive to major tornado outbreaks in the U.S.? J. Climate, 26, 1626-1642, doi:http://dx.doi.org/10.1175/JCLI-D-12-00128.1.**



Acknowledgement



- **NOAA-CPO: Toward developing a seasonal outlook for the occurrence of major U.S. tornado outbreaks. PIs: S.-K. Lee, S. Weaver, R. Atlas, C. Wang and D. Enfield. August 1, 2012 – July 31, 2015.**